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Skeletal muscle fiber-type distribution and habitual physical activity in daily life

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The capacity to perform physical activity largely depends on physical fitness. Muscle fiber-type distribution ($Muscle_{FTD}$) is associated with physical fitness and may influence the capacity to perform physical activity. The purpose of this study was to determine whether habitual physical activity in daily life (PA_{DL}) and $Muscle_{FTD}$ are related. Thirty-eight healthy non-athletes (31 women, 7 men) were recruited. PA_{DL} was measured twice for 14 days using a tri-axial accelerometer for movement registration (Tracmor). From Tracmor output, the proportion of time subjects were physically active at low, moderate, and high intensities was determined (%Low, %Moderate, and %High, respectively). A total activity index (PA_{index}) and sub-scores on work, leisure-time and sports were obtained using the Baecke questionnaire. $Muscle_{FTD}$ was determined using immuno-fluorescence against respective myosin heavy chain isoforms. No relationship was observed between PA_{DL} and $Muscle_{FTD}$. %Low, %Moderate, and %High, as well as PA_{index} and its sub-scores, were not related to $Muscle_{FTD}$ either. The time spent on sports was associated with the proportion of type I and II_X fibers ($P = 0.06$ and $P < 0.01$, respectively). In conclusion, $Muscle_{FTD}$ probably cannot explain why some people are more prone to engaging in physical activities than others.

Activity-related energy expenditure is the most variable component of total energy expenditure (Ravussin & Swinburn, 1992) and appears to be an important determinant of energy balance (Schoeller et al., 1997). This implies that a reduced physical activity is a potentially important contributor to a predisposition to obesity (Heitmann et al., 1997; Weinsier et al., 1998; Esparza et al., 2000; Wardle et al., 2001; Ekelund et al., 2002). In a recent twin study, habitual physical activity in daily life (PA_{DL}) was determined using a tri-axial accelerometer for movement registration. Based on the difference in intra-pair correlation in PA_{DL} between monozygotic and dizygotic twins ($R = 0.88$ and 0.42, respectively), additive genetic factors were concluded to explain 78% of inter-subject variation in PA_{DL} (Joosen et al., 2005). This suggests that genes determine to a large extent whether a person is prone to engaging in physical activities. How PA_{DL} is affected by the genotype remains to be established.

One of the potential factors through which the genetic background could affect PA_{DL} is skeletal muscle fiber-type distribution ($Muscle_{FTD}$) (Komi et al., 1977; Gollnick & Matoba, 1984; Simoneau et al., 1985; Lortie et al., 1986; Simoneau & Bouchard, 1995), defined as the relative number of type I, II_A, and II_X muscle fibers (%Type I, %Type II_A, and %Type II_X, respectively). Based on monozygotic and dizygotic twin studies, it has been estimated that approximately 45% of the variation in %Type I is associated with inherited factors (Simoneau & Bouchard, 1995). $Muscle_{FTD}$ is strongly associated with physical fitness, usually measured by maximal oxygen uptake (VO_{2max}), and might thereby influence the capacity to perform physical activity (Hedman et al., 2002). Indeed, positive associations between leisure-time physical activity ($PA_{leisure}$), measured using questionnaires and interviews, and %Type I have been observed (Tikkanen et al., 1998; Hedman et al., 2002; Karjalainen et al., 2006). Considering the aforementioned, it might well be that part of the genetic contribution to PA_{DL} results from $Muscle_{FTD}$. Therefore, the aim of this study was to examine the association between habitual PA_{DL} and $Muscle_{FTD}$ in a population of healthy, young adults. PA_{DL} was hypothesized to be higher in subjects with a $Muscle_{FTD}$ associated previously with a higher physical fitness, i.e. a higher %Type I and a lower %Type II_X (Gollnick & Matoba, 1984).

Table 1. Subject characteristics

	Men	Women
n	7	31
Age (years)	20 ± 2	20 ± 2
BM (kg)	79.3 ± 14.1	63.1 ± 8.2†
Height (m)	1.84 ± 0.06	1.69 ± 0.06†
BMI (kg/m^2)	23.2 ± 3.0	22.0 ± 2.5

BM, body mass; BMI, body mass index; values are means ± SD.
Significant gender difference: $^{\dagger}P<0.001$.

Materials and methods

Subjects

Based on an effect size of 0.25, a power calculation indicated that 33 subjects are required for a power of 0.8 in simple linear regression analyses. Taking a dropout rate of 15% into account, 38 healthy, non-smoking subjects (31 females, 7 males) aged 20 ± 2 years were recruited to participate in this study. Subjects were not using any medication except for oral contraceptives. Recruitment was carried out using flyers in the university building. Subjects spending over 2 h/week on endurance sports, or 5 h on sports in general, were excluded from participation to minimize the effect of exercise training on $Muscle_{FTD}$. The subjects who were recruited either did not participate in sports or met the aforementioned criterion. These subjects participated in sports on a recreational basis and in a wide range of sports. Information about the purpose and protocol of the study, as well as its risks and discomfort were provided both orally and in writing. All subjects provided written informed consent before participating in the study. The study conformed to the standards set by the Declaration of Helsinki, and the local Ethics Committee approved the study. Subject characteristics ($n = 38$) are presented in Table 1.

PA_{DL}

PA_{DL} was measured using a tri-axial accelerometer for movement registration (Tracmor IV; Philips Research, Eindhoven, the Netherlands) sensitive to a wide range of body movements. The accelerometer has been validated against doubly labeled water, the gold standard for measuring energy expenditure in daily life (Plasqui et al., 2005). The Tracmor registers accelerations of the trunk along the antero-posterior, medio-lateral, and longitudinal axes using three uni-axial piezo-electric accelerometers (details are provided elsewhere; Plasqui et al., 2005). To ensure a valid reflection of long-term daily life activities, the accelerometer was worn for two 14-day periods under free-living conditions. Subsequently, PA_{DL} was acquired by summing the output of all three axes and is represented as Megacounts per day (Mcnts/day). PA_{DL} was defined as the average of both measurement periods.

Subjects were instructed to wear the Tracmor from the moment they woke up in the morning until they went back to bed at night. To verify whether subjects lived up to this instruction, waking hours and clock times of wearing the Tracmor were noted. To make sure only representative days were included, the difference between the total time the subject was awake and the time the accelerometer was worn was not allowed to exceed 75 min/day. The few days during which this difference was more than 75 min were excluded from the analysis. This resulted in an average of 26 representative days per subject. To make sure the subjects met the inclusion criterion concerning their participation in sports, the actual sporting hours were also recorded in the diary.

Using Tracmor data, the proportion of time subjects were physically active at a low, moderate, and high-intensity (%Low, %Moderate, and %High, respectively) was determined. The cut-off points for the intensity categories were determined in a pilot study ($n = 5$). The cut-off point for low-intensity physical activity was set by Tracmor outputs associated with walking on a treadmill at 3.5 km/h, which corresponds with approximately 3 metabolic equivalents (METs). For moderate-intensity physical activity, a Tracmor output associated with walking on a treadmill at 5 km/h was used, which corresponds with approximately 4.5 METs (Ainsworth et al., 2000). The relevant Tracmor outputs were 16.0 ± 3.0 Mcnts/min and 28.9 ± 3.0 Mcnts/min, respectively. The proportion of time per intensity category was calculated as the sum of all minutes per intensity category divided by the total duration of the measurement, i.e. 28 days minus the number of excluded days.

Using linear regression analysis in a population similar to the present study with respect to PA_{DL}, body composition and age, Plasqui et al. (2005) were able to predict physical activity level (PAL) with an explained variation of 70% using only PA_{DL}. This regression equation was used in the present study to estimate PAL.

Measures for physical activity during work, sports and leisure-time were obtained using the Baecke questionnaire (Baecke et al., 1982). Summing the scores of each section provided a total activity index (PA_{index}). Like the Tracmor, the Baecke questionnaire has been validated against doubly labeled water, with the PA_{index} explaining 45% of the variation in PAL (Philippaerts et al., 1999).

Muscle sample analysis

A muscle biopsy was obtained from the M. Vastus Lateralis under local anesthesia (xylocaine 2%) using a Bergström needle with suction (Bergstrom, 1975). The Vastus Lateralis was selected because of the absence of large vessels or nerves in the region, the presence of type I, II_A, and II_X muscle fibers in an ample amount (Staron et al., 2000) and the large inter-individual variation in $Muscle_{FTD}$ (Edstrom & Nystrom, 1969; Staron et al., 1994). Biopsies were frozen in melting isopentane and stored in a pre-cooled aluminum cryo-vial at −80 °C until analyzed.

Serial transverse cryosections were cut (5 μm) in a crysostat microtome (Leica; CM 3050, Rijswijk, the Netherlands) and thaw-mounted on uncoated pre-cleaned glass slides. After air-drying for ~120 min, sections were again stored at −80 °C until processing for routine immunofluorescent staining against distinct myosin heavy-chain (MHC) isoforms.

Muscle fibers were characterized as type I, II_A, or II_X using antibodies against the respective MHC isoforms. Briefly, air-dried cryosections were treated for 5 min with 0.5% triton X-100 in phosphate-buffered saline (PBS), and washed for 5 min with PBS. Thereafter, a 0.05% Tween20/PBS dilution containing the primary antibody for MHCI diluted 1:50 (A4.840; DSHB, Iowa city, Iowa, USA), $MHCII_A$ diluted 1:50 (N2.261, DSHB) and anti-laminin diluted 1:200 (L-9393; Sigma, Zwijndrecht, the Netherlands) was applied for 45 min. After three 5-min washes with PBS the appropriate secondary antibodies [Alexa Fluor 555 Goat anti-Mouse IgM diluted 1:500 (A-21426), Alexa Fluor 488 Goat anti-Mouse IgG1 diluted 1:200 (A-21121), and Alexa Fluor 350 Goat anti-Rabbit IgG diluted 1:130 (A-11069) (Molecular Probes Invitrogen, Breda, the Netherlands)] were applied for 45 min at room temperature. Again, sections were washed with PBS three times for 5 min and embedded in Mowiol 4-88 (475904, Calbiochem, Amsterdam, the Netherlands).

After 24 h, the slides were examined using a Nikon E800 Fluorescence microscope (Uvikon, Bunnik, the Netherlands). Images were captured using a color CCD camera (Basler 113C, Basler vision technologies, Ahrensburg, Germany) with MHCI in red, $MHCII_A$ in green and laminin, a basement membrane marker to identify the myofiber boundary, in blue. All fibers without intracellular staining were considered to be type II_X muscle fibers.

Digitally captured images (× 20 magnification) were processed and analyzed using Lucia 4.8 software (Nikon; Düsseldorf, Germany). Muscle fiber typology was measured semi-automatically using a custom-written macro that identifies individual muscle fibers. Upon thresholding, red (MHCI), green ($MHCII_A$), and unstained fibers ($MHCII_X$) were identified and expressed as percentage of the total number of fibers identified. On average, $Muscle_{FTD}$ was determined in 290 ± 135 fibers/subject.

Maximal oxygen uptake

VO_{2max} was determined during an incremental maximal intensity test on a calibrated electromechanically braked cycle ergometer (Lode Excalibur; Lode, Groningen, the Netherlands). The initial workload was set at 100 W for men and 75 W for women. Subjects were instructed to maintain their crank rate between 80 and 100 r.p.m. at all times during the test. After 5 min of warming up, workload increased with 50 W every 2.5 min until exhaustion. Exhaustion was defined as a sudden decline in crank rate below 60 r.p.m., usually resulting in the subjects giving up. Throughout the test, gas exchange was measured continuously using an Oxycon β (Oxycon; Mijnhardt, Bunnik, the Netherlands). The analyzer was calibrated daily using a 3-L calibrated syringe (Sensormedics, Anaheim, CA, USA) and a gas mixture of known concentration (5.0% CO_2, 95.0% N_2). VO_{2max} was determined using a third-order polynome fitted through the data. The maximum of this polynome was considered the VO_{2max}.

Body composition

Fat-free mass (FFM) and fat mass (FM) were determined as subject comparative measures for body composition. Therefore, anthropometric measurements were carried out in the morning after an overnight fast. Body mass was measured on an electric scale (ID 1 Plus; Mettler Toledo, Giessen; Germany) to the nearest 0.01 kg. Height was measured to the nearest 0.1 cm (Model 220; SECA, Hamburg, Germany). Body volume was determined using the underwater weighing technique while correcting for residual long volume using the helium dilution technique (Volugraph VG 2000; Mijnhardt). Total body water was determined overnight using the deuterium dilution technique according to the Maastricht protocol (Westerterp et al., 1995). Body composition was subsequently calculated from body volume and total body water using Siri's three-compartment model (Siri, 1993).

Statistics

Differences between men and women were tested using Student's *t*-tests for unpaired samples. Differences in PA_{DL} between the two measurement periods were evaluated using a Student's *t*-test for paired samples. Bivariate correlation was used to test the association between parameters of physical activity and $Muscle_{FTD}$. To evaluate the relationship between %Low, %Moderate, %High, and the time spent on sports with $Muscle_{FTD}$, variables were log transformed. This transformation was applied to obtain a normal distribution of the residuals with homoskedasticity, i.e., an equal variance over the entire range of predicted values. Statistical analysis was carried out using the Statistical Package for Social Sciences (SPSS) version 11 for Macintosh OSX (SPSS Inc., Chicago, Illinois, USA). Data are expressed as means ± SD. For associations, unstandardized coefficients and 95% confidence intervals, as well as *P*-values are provided. *P*-values <0.05 were considered statistically significant.

Results

PA_{DL} was not significantly different between the two 14-day measurement periods ($P = 0.14$). Results on PA_{DL} averaged over both periods, as well as on the proportion of time spent in each intensity category are presented in Table 2. PA_{index} and Baecke subscores, as well as the weekly time spent on sports, $Muscle_{FTD}$, VO_{2max} and body composition are also shown in Table 2.

PA_{DL} was comparable for men and women: 4128 vs 3704 Mcnts/day, respectively (Table 2). The proportion of time spent in each intensity category was comparable between genders as well, although

Table 2. Data on physical activity, muscle fiber type distribution, and body composition

	Men	Women
PA_{DL} (Mcnts/day)	4128 ± 636	3704 ± 675
PAL	1.88 ± 0.10	1.80 ± 0.11
%Low (/24 h)	96.5 ± 1.0	97.3 ± 1.0
%Moderate (/24 h)	2.3 ± 0.5	2.1 ± 0.9
%High (/24 h)	1.2 ± 0.8	0.7 ± 0.4§
PA_{index}	8.1 ± 1.0	8.6 ± 0.9
Baecke work	2.0 ± 0.3	2.2 ± 0.3
Baecke sport	3.2 ± 0.7	3.0 ± 0.6
Baecke leisure	3.0 ± 0.3	3.4 ± 0.4*
Sports (h/week)	2.2 ± 1.8	2.1 ± 1.7
%Type I	56.6 ± 12.9	59.6 ± 10.6
%Type II_A	39.4 ± 11.6	37.1 ± 10.3
%Type II_X	3.9 ± 3.9	3.3 ± 5.1
VO_{2max} (L/min)	4.0 ± 0.8	2.7 ± 0.4†
VO_{2max} (mL/min/kg BM)	51.1 ± 5.1	42.8 ± 4.7†
VO_{2max} (mL/min/kg FFM)	60.8 ± 4.8	58.4 ± 5.7
FFM (kg)	66.3 ± 9.9	46.0 ± 4.6†
FM (kg)	13.0 ± 6.3	17.1 ± 4.8

PA_{DL}, physical activity in daily life as measured using a tri-axial accelerometer during two periods of 2 weeks; Mcnts/day, Megacounts per day; PAL, physical activity level, i.e., the factor by which total energy expenditure exceeds resting energy expenditure; %Low, %Moderate, and %High, proportion of time subjects were physically activity at a low, moderate, and high-intensity respectively; PA_{index}, total activity index measured with the Baecke questionnaire; Baecke Work, Sport, and Leisure, scores on each section of the Baecke questionnaire; Sports, weekly time spent on sports in hours; FFM, fat-free mass; FM, fat mass; %Type I, %Type II_A, and %Type II_X, proportion of type I, II_A, and II_X muscle fibers; VO_{2max}, maximal oxygen uptake, either absolute, or relative to body mass or FFM; Data are means ± SD.

Significant gender difference: $^{*}P<0.05$; $^{§}P<0.01$; $^{†}P<0.001$.

%High was significantly higher in men: 1.2% vs 0.7% in women ($P<0.01$). Men and women combined were physically active at a low, moderate, and high-intensity for approximately 97%, 2%, and 1% of the time, respectively. This corresponds with 30 and 11 min of moderate and high-intensity physical activity per day. Application of the regression equation developed by Plasqui et al. (2005) to the present population showed that the PAL ranged from 1.62 to 2.04. $Muscle_{FTD}$ was not significantly different between genders, which confirms the findings of previous studies (Bell et al., 1980; Kriketos et al., 1997; Evertsen et al., 1999; Staron et al., 2000; Jaworowski et al., 2002). When averaged for both genders, $Muscle_{FTD}$ was approximately 59% type I, 38% type II_A, and 3% type II_X.

No difference was found between men and women for the PA_{index} and Baecke sub-scores on work and sports (Table 2). Only the Baecke sub-score for physical activity during leisure-time was significantly

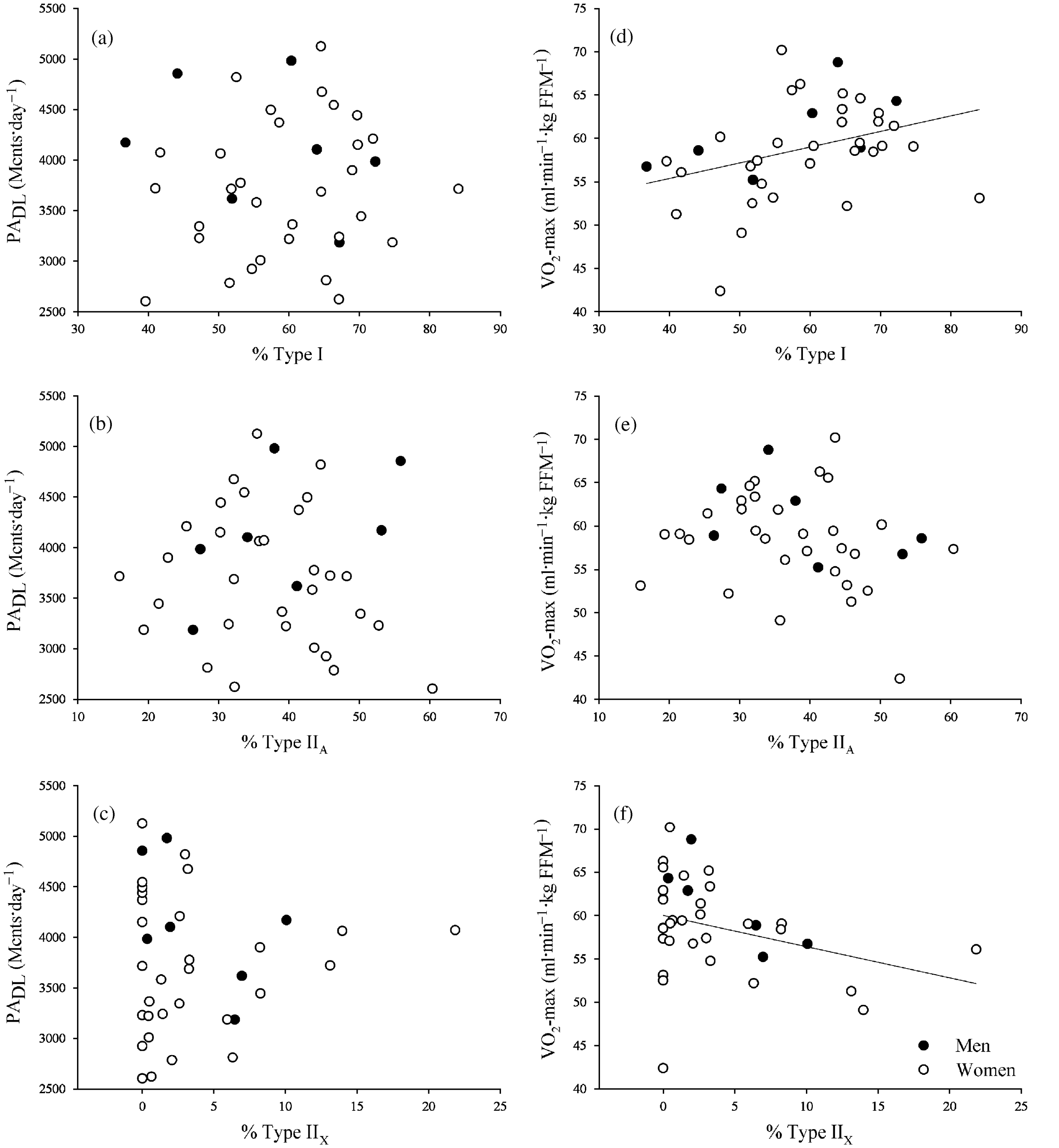

Fig. 1. Habitual physical activity in daily life and maximal oxygen uptake per kg fat-free mass as a function of muscle fiber-type distribution. (a–c) Show habitual physical activity in daily life (PA_{DL}) as a function of the proportion of type I, II_A, and II_X muscle fibers, respectively. (d–f) Show maximal oxygen uptake (VO_{2max}) expressed per kg fat-free mass (FFM) as a function of the proportion of type I, II_A, and II_X muscle fibers, respectively.(d) $P<0.05$; (f) $P=0.05$.

different between genders: 3.0 ± 0.3 vs 3.4 ± 0.4 for men and women, respectively ($P<0.05$). The weekly time spent on sports did not differ between genders (Table 2). On average, subjects reported spending approximately 2 h/week on sports, which corresponds with approximately 17 min/day.

FFM is the strongest independent predictor of VO_{2max}, alone explaining 86% of its variation ($P<0.001$). Although VO_{2max} was significantly higher in men than in women, this difference did not remain after adjusting VO_{2max} for FFM. Based on these results, both genders were combined for further analyses.

VO_{2max} expressed per kilogram FFM was positively associated with %Type I ($R^2 = 0.13$; $P<0.05$), and correlated borderline significantly with %Type II_X ($R^2 = 0.10$; $P = 0.05$) (Fig. 1). A trend towards a positive association was observed between PA_{DL} and VO_{2max} adjusted for FFM ($P = 0.09$). PA_{DL} on the other hand was not significantly associated with $Muscle_{FTD}$ (P-values >0.7) (Fig. 1). No associations were found between %Low, %Moderate, and %High with $Muscle_{FTD}$ either (P-values ≥ 0.2). Moreover, neither the PA_{index} nor the Baecke subscores were significantly correlated with $Muscle_{FTD}$ (P-values ≥ 0.2). On the contrary, the time weekly spent on sports was negatively associated with %Type II_X ($R^2 = 0.19$; $P<0.01$) and tended to correlate positively with %Type I ($R^2 = 0.09$; $P = 0.06$) (Fig. 2). All unstandardized regression coefficients, 95% confidence intervals and P-values are provided in Table 3.

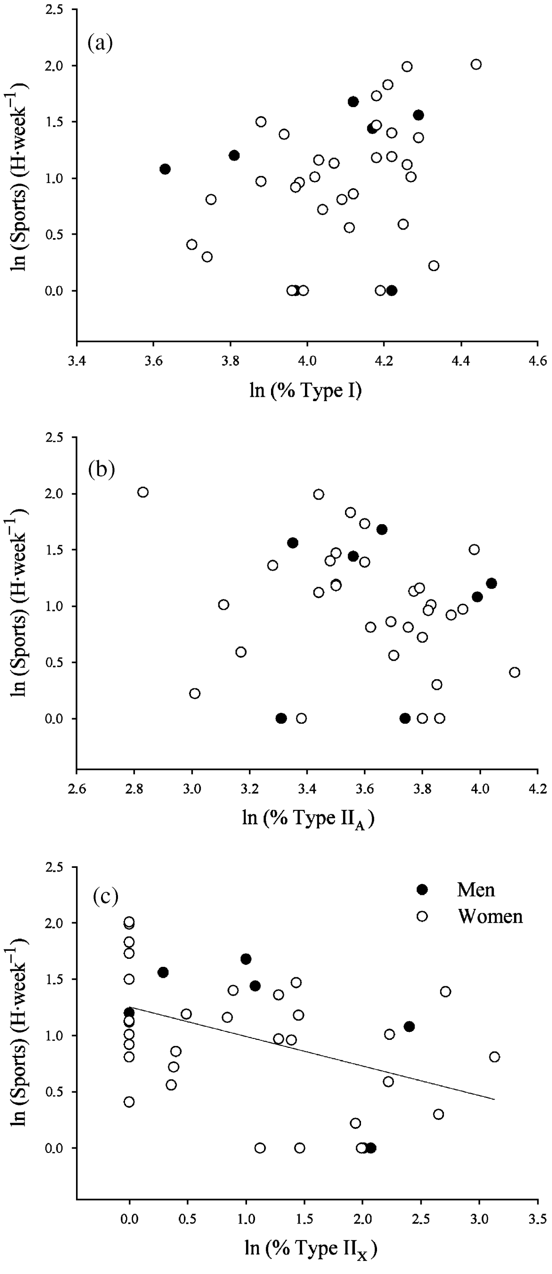

Fig. 2. Time spent on sports in h/week and the proportion of type I (a), II_A (b), and II_X (c) muscle fibers after natural log (ln) transformation of both variables. (a) $P = 0.06$;(c) $P<0.01$.

Discussion

The capacity to perform physical activity was proposed previously to depend on physical fitness (Tikkanen et al., 1998; Hedman et al., 2002). Since $Muscle_{FTD}$ was shown to be strongly associated with physical fitness (Hedman et al., 2002), the former was considered to be a candidate to explain (part of) the inter-individual variation in PA_{DL}. The aim of this study was thus to determine whether habitual physical activity in daily life was associated with $Muscle_{FTD}$. To this end, PA_{DL} was measured for two periods of 14 days using the Tracmor, a validated triaxial accelerometer for movement registration. The previously observed associations between physical activity and VO_{2max} and between VO_{2max} and $Muscle_{FTD}$ were confirmed in the present study. This affirms $Muscle_{FTD}$ as a candidate to influence the capacity to perform physical activity.

To prevent an effect of physical exercise training on $Muscle_{FTD}$, subjects spending more than 2 h/week on endurance sports or more than 5 h/week on sports in general were excluded from participation. This resulted in an average engagement in sports of 2 h/week. Still, a wide range in PA_{DL} was observed and the range in PAL observed indicates that sedentary as well as highly physically active subjects were recruited (Black et al., 1996; Westerterp, 2001).

No evidence was found for a relationship between PA_{DL} and $Muscle_{FTD}$. The accelerometer used in this study was also used by Joosen et al. (2005), who showed that the largest part of inter-subject variation in PA_{DL} results from genetic variation. Hence, our results suggest that $Muscle_{FTD}$ probably

Table 3. Unstandardized regression coefficients, 95% confidence intervals and P-values for all associations with muscle fiber type distribution

	%Type I				%Type II_A				%Type II_X			
	B	95% CI		P	B	95% CI		P	B	95% CI		P
PA_{DL}	2.7	−18.3	23.6	NS	−3.1	−25.1	19.0	NS	0.6	−46.7	48.0	NS
%Low (24/h)	−0.002	−0.02	0.02	NS	−0.003	−0.02	0.01	NS	0.002	−0.002	0.006	NS
%Moderate (24/h)	0.06	−0.5	0.7	NS	0.005	−0.4	0.4	NS	−0.04	−0.2	0.08	NS
%High (24/h)	0.1	−1.1	1.3	NS	0.2	−0.6	1.0	NS	−0.1	−0.4	0.09	NS
PA_{index}	0.01	−0.02	0.04	NS	−0.01	−0.04	0.02	NS	−0.01	−0.07	0.05	NS
Baecke work	−0.002	−0.01	0.008	NS	−0.0005	−0.01	0.01	NS	0.01	−0.01	0.03	NS
Baecke sport	0.007	−0.01	0.03	NS	−0.001	−0.02	0.02	NS	−0.03	−0.07	0.01	NS
Baecke leisure	0.005	−0.009	0.02	NS	−0.007	−0.02	0.007	NS	0.01	−0.02	0.04	NS
Sports (h/week)	0.9	0.05	1.9	NS	−0.4	−1.0	0.3	NS	−0.3	−0.5	−0.08	<0.01
VO_{2max} (mL/min/kg FFM)	0.2	0.02	0.3	<0.05	−0.1	−0.3	0.06	NS	−0.4	−0.7	0.01	0.05

B, Unstandardized regression coefficient; 95% CI, 95% confidence interval of B; PA_{DL}, habitual physical activity in daily life in Megacounts per day; %Low, %Moderate and %High, proportion of time subjects were physically activity at a low, moderate and high intensity, respectively; PA_{index}, total activity index measured with the Baecke questionnaire; Baecke Work, Sport and Leisure, scores on each section of the Baecke questionnaire; Sports, weekly time spent on sports in hours; VO_{2-max}, maximal oxygen uptake expressed in ml O_2 per minute per kg fat-free mass; %Type I, %Type II_A and %Type II_X, proportion of type I, II_A and II_X muscle fibers.

cannot explain the large inter-individual variation in PA_{DL} that results from genetic variation. In concurrence with this finding, no association was found between the PA_{index} and $Muscle_{FTD}$. Moreover, no relationship was observed between %Low, %Moderate, and %High with $Muscle_{FTD}$, indicating that $Muscle_{FTD}$ does not affect the proportion of time subjects spend in each of the three intensity categories.

Subjects spent 30 and 11 min/day on moderate and high-intensity physical activity, respectively. These values are close to those recently reported in other studies that used accelerometry in healthy, young adults (Yoshioka et al., 2005; Dinger & Behrens, 2006). McClain et al. (2007) recruited regular runners and obtained a %Moderate similar to that observed in the present study (27 min/day). %High, on the other hand, was more pronounced in the subjects recruited by McClain et al. (48 min/day). This suggests that although highly physically active subjects were evidently recruited in the present study, the proportion of high-intensity physical activity was lower than observed previously for people actively engaged in endurance sports.

The association between $PA_{leisure}$ and $Muscle_{FTD}$ found by others (Tikkanen et al., 1998; Hedman et al., 2002; Karjalainen et al., 2006) was not affirmed in the present study. This discrepancy may partly result from a difference in the health status of the subjects. Contrary to our population, which contained only healthy subjects, Hedman et al. (2002) recruited subjects from a cohort of 70-year-old men. When performing the analysis on healthy subjects only, no association between $PA_{leisure}$ and $Muscle_{FTD}$ remained. In the study of Tikkanen et al. (1998) and a recent follow-up study in the same population (Karjalainen et al., 2006) only healthy subjects were recruited. However, the method used in these studies to assess $PA_{leisure}$ did not distinguish between physical activity during leisure-time and sports. As an association between the weekly time spent on sports and $Muscle_{FTD}$ was observed in the present study, we speculate that the relationship between $PA_{leisure}$ and $Muscle_{FTD}$ found by Tikkanen et al. and Karjalainen et al. actually resulted from sports rather than leisure-time *per se*.

On average, subjects reported to spend 2 h/week on sports. A significant relationship was observed between the time weekly spent on sports and %Type II_X. The power of this association was 0.84 ($\alpha = 0.05$, one predictor, $R^2 = 0.19$, $n = 38$). Furthermore, the weekly time spent on sports tended to correlate positively with %Type I. Owing to the cross-sectional design of this study, no conclusions about causality can be drawn. However, previous studies showed that both endurance and strength training can induce a shift in $Muscle_{FTD}$ from type II_X to type II_A, i.e., toward a more oxidative phenotype (Andersen & Henriksson, 1977; Ingjer, 1979; Howald et al., 1985; Simoneau et al., 1985; Sale et al., 1990; Coggan et al., 1992; Staron et al., 1994). For example, Staron et al. (1994) showed that in untrained subjects, %Type II_X decreased significantly already after four sessions of strength training within 2 weeks. This implies that even a small difference in training status may have resulted in the relationship found between the time spent on sports and %Type II_X. The decreased %Type II_X is therefore considered an effect rather than a cause of an increased time spent on sports.

Contrary to transitions from type II_X to type II_A, the majority of studies performed did not find an increased %Type I following a period of either endurance or strength training (Gollnick et al., 1973; Saltin et al., 1976; Andersen & Henriksson, 1977; Ingjer, 1979; Coggan et al., 1992; Staron et al., 1994). For example, %Type I was not altered after 24 weeks of intensive endurance training in previously untrained women (Ingjer, 1979). Therefore, the increased time spent on sports may actually result from an increased %Type I. In other words: subjects with a higher %Type I may be more prone to engaging in sports. Since the time spent on sports was used as an exclusion criterion, its range was limited. This may explain why the association with %Type I did not reach significance.

In conclusion, $Muscle_{FTD}$ probably cannot explain why some people are more prone to engaging in physical activities than others. To generalize the findings, the measurements should be replicated.

Perspectives

The association between PA_{DL} and $Muscle_{FTD}$ was determined for the first time, using an objective and validated method to determine physical activity for a prolonged period of time. In spite of the association between physical fitness and $Muscle_{FTD}$, no evidence was found for a relationship between PA_{DL} and $Muscle_{FTD}$. This indicates that physical fitness and physical activity are two non-synonymous entities that should not be used interchangeably. It also suggests that variables other than $Muscle_{FTD}$ probably determine why some people are more physically active than others. Future research is required to identify these variables.

Key words: accelerometers, myosin heavy chain isoforms, sports, exercise, heredity.

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